cycles

April 1960

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CYCLES

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INDEX

BY DEPARTMENT

Cycle Round-Up
  Latest available figures and chart of Standard & Poor's Combined Index 80

Director's Letter 75

Foundation Reprint No. 40
  The Rhythmic Nature of Animals and Plants
    by Frank A. Brown, Jr.. 81

Geisinger Indicator of
  Industrial Production 94

Letters
  Corn and Hog Cycles, The Stock Market, Politics. 93

Research by Staff
  The Trend of the Revised F.R.B. Index of Industrial Production. 77

Research by Others
  Dunbars 46-Month Stock Price Cycle 78

BY SUBJECT

Business
  Aluminum Production 80
  Automobile Production 80
  Cotton Consumption. 80
  Industrial Production 77, 94
  Residential Building. 80
  Shoe Production 80
  Unemployment. 80

Commodity Prices
  Cocoa Beans 80
  Copper. .80
  Corn. 80
  Eggs. 80
  Hogs. 80
  Oats. 80
  Soybeans. 80
  Wheat 80

Finance
  Bond Yields 80
  Liabilities of Failures 80
  Stock Prices. 78,.80

Science
  The Rhythmic Nature of Animals and Plants. 81

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Director's Letter

Dear Member:

One of our good and wise members has written to censure me for not telling you about the present economic situation as I see it. His name is Lee McCanliss. He is a lawyer. He was Chairman of the Board of Trustees of Wabash College. He has seen (and foreseen) many business ups and downs. He thinks we are in a precarious economic situation. He thinks I should emphasize this fact in my letters to you. His letter was printed on page 64 of *Cycles* for March.

Another member, Joseph Benjamin of County Sligo, Ireland, asks me why I join the "conspiracy of silence" relative to the underlying economic weakness of the U. S. A.

The answer is,

I'm supposed to deal with fact—not with opinion. Moreover, I'm supposed to limit myself to a particular kind of fact—namely cycles. It's not my province to splash my opinions on the pages of *Cycles* My opinions are based on many things in addition to cycles. But my opinions may be wrong. If so, this fact would cast discredit on cycles and perhaps set back our subject for many years.

A Conspiracy of Silence

Is there an unconscious conspiracy of silence? I suspect there is. There could be several reasons for such a conspiracy.

People seem to feel that prosperity is based upon universal belief in more prosperity. That the failure of people generally to uphold this belief might bring on a recession. That a recession might spiral into a depression.

Some years ago there was a Frenchman named Coué who proclaimed that health could be attained by saying to oneself over and over again, "Every day in every way I am getting better and better." Many businessmen seem to feel that the same formula will work in our economy.

I suspect that, to a certain extent, both Monsieur Coué and the businessmen are right. I believe in a positive mental attitude. But in both instances the matter can be overdone. The use of a verbal formula may deter someone with a serious ailment from seeing a doctor. The exuding of excessive optimism may encourage over-expansion to a degree that will, of necessity, cause the structure to fall of its own weight.

"Faster! Faster!" said the Red Queen (I quote from memory).

"Why?" said Alice.

"Because, in this place, one has to run with all one's might just to stand still!"

Eventually things get to such a pace that even running with all one's might isn't enough. Then things go back.

A second reason for a possible conspiracy of silence is the fact that people like the pleasant, dislike the unpleasant. Writers and news media pander to this fact. The headlines puff any advance, soft pedal any decline; play up good news, play down the bad. Even worse, the readers themselves fail to give equal weight to good news and bad. They cling to anything that offers hope, no matter how frail.

A third reason for thinking that there may be a conspiracy of silence is to be found in the old Chinese adage, "Those who know do not speak; those who speak do not know." One reason for this state of affairs may be the ridicule that descends upon the man who sees too far ahead of his fellows. People who can see around the corner get laughed at. They learn to clam up. For example, Joe Barber, former economist for the Walworth Company once told me that, to start with, he used to call the turns six months ahead. He was laughed at. In time he learned to wait until the signs of a change were clearer to his listeners. Then his pronouncements would be accepted!

Finally there is the fact that the majority is mostly wrong. This is why I like the idea behind CONTRARY OPINION, a service published by my friend Humphrey Neill of Saxton's River, Vermont. Humphrey scans the papers for the consensus and then presents the *opposite* view. Many of our members take his service and like it. (Why not send him $5 for a trial subscription?)

I have no desire to join this so-called conspiracy of silence. If I had, I would not have printed (in the April 1959 issue of *Cycles*) the chart of stock prices from 1835 which showed that 1958 prices were 109% above the basic underlying growth trend. (1959 prices were 155% above trend). It also showed, you will remember, that only twice before in our history had we recorded such a perilous height—in 1835 before the panic of 1837 and in 1929 before the depression of the early 1930's. The same chart showed that previous reaction to such excesses brought prices down to as much *below* trend as the peaks had been above. You need to know these things.

Democracy

I don't know why we are so proud of a system of government that is based (at least theoretically) upon the wisdom of the *average* man instead of upon the wisdom of the *superior* man. In your town for example don't you feel that you and all the other leading citizens could vote much more intelligently than the great mass of the uninformed?

Of course the real rub is not that we are governed by the mediocre, because we are not, really. Much worse! We are governed by selfish minority pressure groups—farmers, veterans, manufacturers, railroaders, labor leaders and scores of others, all in tugs of war to exploit each other and the rest of us. It's a wonder we survive!

Visitors

I am indebted to the Sun Printing House of Philadelphia 44, Pa. for the following notice to visitors:

Friendly Calls.	2 minutes
Friendly Calls (when busy).	1 minute
Magazine Salesmen	4 seconds
Stocks & Bonds.	3 seconds
Friends with Tips on the Horses . . .	½ second
Friends Looking for Free Meal	Too Busy
Friends Inviting Us to Lunch.	Two Hours
Legitimate Business . .	Always at Your Service

This notice reminds me of a gas station I once passed in some California back country. Nothing was in sight except the gas pump, a little shack, and this sign:

"For gas, ring bell once.
For oil, ring bell twice.
To borrow tools, ring bell three times and run like hell!"

How to Make a Cycle Analysis

This sign, in turn, reminds me of letters I get every little while which read, "Please tell me how to make a cycle analysis."

Of course I've done this, as best I know, in a 700-page course, but people want it in a *letter*!

Profit

Some people look down their noses on Profit. Nothing could be more fallacious! Profit is the difference between social value and social cost. That is, if you make, at a cost of $800, some duhinguses for which people will pay $1,000 there is a clear *social* gain of $200. If, by efficiency, you can cut the cost to $600 there is a social gain of twice as much. Profit is the source of savings and of labor saving devices (capital). It can be thought of as a measure of efficiency. The tendency of some government officials, some labor leaders, and some egg-heads to look down upon profit shows that they just don't understand what makes things tick.

The present tax structure, discouraging profit making, is abominable. (Democracy again!—Pandering to the masses !)

The Next Depression

One good thing about thinking in terms of cycles is that you are always one jump ahead. As things go up you are thinking of the coming decline; as they go down you are thinking of the coming rise. Right now, near the peak of the boom, is a good time to start thinking of the depression to come.

The right way to cure a real depression is for every single person to put his or her shoulder to the wheel. Manufacturers should cut prices *to direct costs,* labor should work for an absolute minimum, or less. And so on. If this were done things would soon start moving again.

Naturally neither manufacturers nor workingmen wish to do this. They hold out as long as they can. Anything that helps them to hold out will deepen and prolong the depression.

Agreements among producers to maintain prices are rare. Anyway they are of little avail. But unemployment insurance, pensions to the able bodied, union contracts, and particularly the emphasis placed by the average working man on *rates per hour* (in contrast to take-home pay per month), are all important elements in preventing recovery. The present tax structure too, is another element that will make the next real depression unnecessarily long and severe.

This is the time we should start thinking about such things. Not in the future when it will be too late.

The Last Depression

During the last depression I had a nice snug berth as a bureaucrat in the U. S. Department of Commerce. One of my jobs was to read and answer all the letters regarding the depression and how to cure it. Most of the ideas were crackpot, of course, but I remember one letter that hit the nail on the head. It was along the lines of the preceding paragraph. The writer wanted the government to proclaim this course of action as the answer. His letter was absolutely sound economically. But *politically*, oh boy! Can you imagine *any* government, depending upon the votes of the masses, publicly advocating lower wage rates? I was sorry to see the letter go into the scrap basket. It could have cured the depression.

Cordially yours,

Edward R. Dewey

Director

Research by Staff

THE TREND OF THE REVISED F.R.B. INDEX OF INDUSTRIAL PRODUCTION

By Edward R. Dewey

SUMMARY

The recent revision of the F.R.B. Index of Industrial Production does not change the conclusions I expressed in June of 1959. These are that industrial production in this country grew only about 2/5 as fast in the period 1953—1959 as in the period 1947—1953.

If the new index goes much above 170 in the next few months (it was 169 in January) it will be a very good sign. If, however, during 1960 or 1961, it drops much below 140, it will be an important warning.

The Federal Reserve Board has revised its Index of Industrial Production. It is, therefore, in point for me to revise my article of June 1959 relative to the trend of these figures.

Trend is the underlying tendency of a series of figures. It is that element that changes its direction *slowly*.

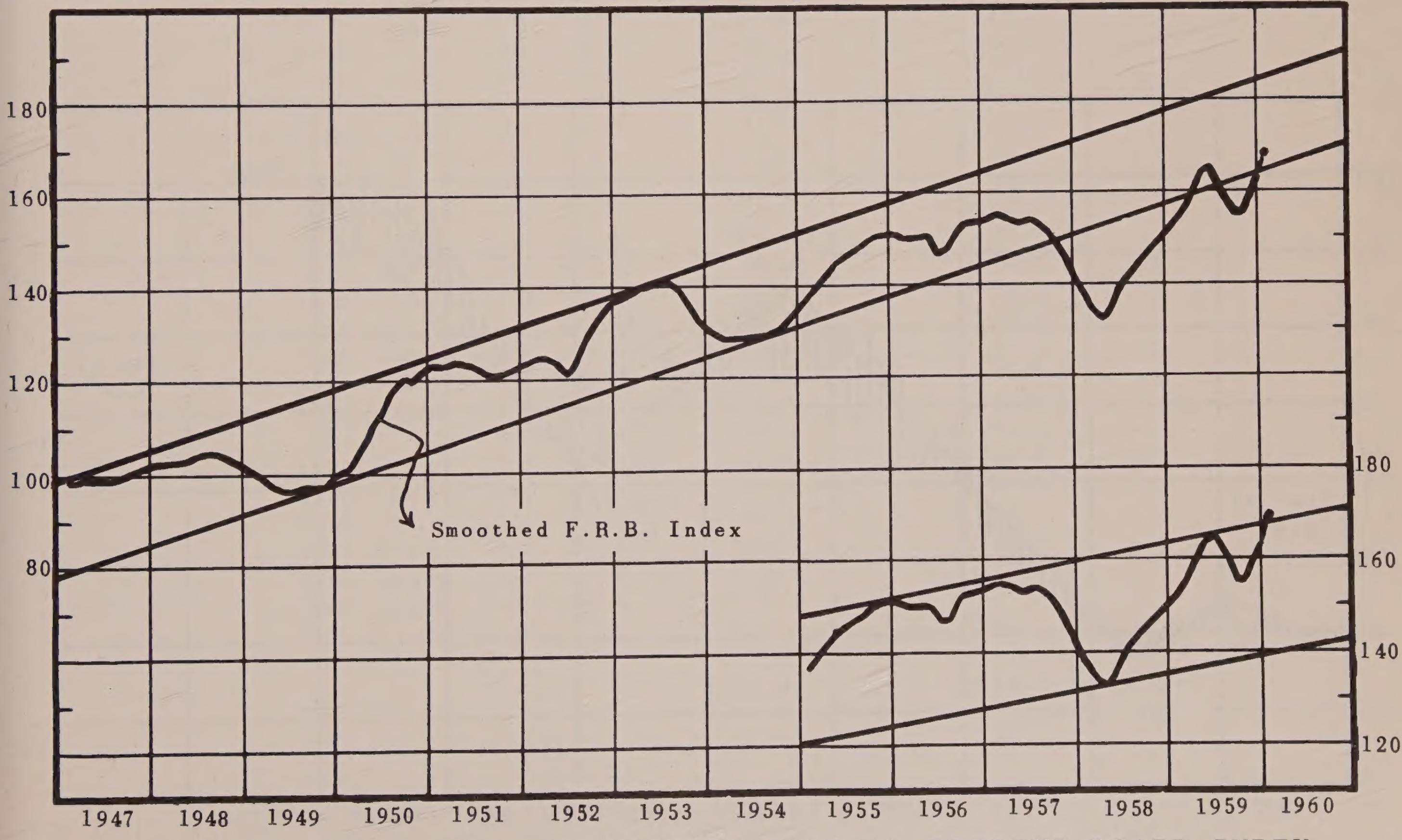
The new F.R.B. Index raises the index by about eight points, but it makes no important difference in the shape of the curve, nor in the conclusions reached last June. These are that industrial production is still forging ahead, but at a rate which is only about 2/5 as great for the period 1953 to 1959 as for the period 1947 to 1953.

If we had continued at the 1947—1953 rate of growth, the index for last December would have stood at about 185 instead of at 165!

If the new index gets much above 170 in the next few months, it will be a very good sign indeed. Conversely, if, during 1960 or 1961, it should drop much below 140, it would be an important warning.

The Trend of Industrial Production

	Old Index	New Index
Mid 1947	101	101
Mid 1953	136	141
Mid 1959	154	165
Increase 1947-53	34.7%	39.6%
Increase 1953-59	13.2%	17.0%
Present rate vs old rate	38%	43 %



TREND SINCE 1947 OF THE REVISED FEDERAL RESERVE BOARD INDEX

Research by Others

DUNBAR'S 46-MONTH STOCK PRICE CYCLE

By G. Shirk

In the June 30, 1952 issue of *Barron's* an article by Veryl L. Dunbar discussed a 46-month cycle in stock prices. According to this cycle, 1960 was to be a year of high. That is, in 1960 a high would develop which would be higher than the low value in the previous year of low, which was 1957.

This has happened.

The January 1960 high of the Axe-Houghton Index of Industrial Stock Prices was 990.9, which is 59.1% above the 1957 low index value of 623.0. This is the fifth time out of the five possibilities since the cycle was first written about that it has worked correctly.

We have extended the work from 1952 to 1960 using the Axe-Houghton Index because this index was used in the original *Barron's* story. The Dow-Jones Average would have worked as well.

The pattern of this cycle is: the years of ideal low follow a schedule of 3-4-4-4-4-4 years, and repeat; the years of ideal high also follow a 3-4-4-4-4-4 schedule. The record of the years of low, and the years of high is given on the next page.

The cycle operates in this manner: during a scheduled year of high, there will be a value higher than the low value of the previous scheduled year of low. During the low year of the cycle, there will be a value which is below the high value of the previous year of high.

The low value during 1957, the last year of low, was 623.0. For the cycle to "work out", 1960 should have a value above 623.0. This has already happened, as the high value of the Axe-Houghton Index was 990.9 in January. Regardless of what happens to the index during the balance of the year, the cycle has worked again.

The chart below diagrams the Dunbar cycle.

The 1952 high was above the 1949 low.

The 1953 low was below the 1952 high.

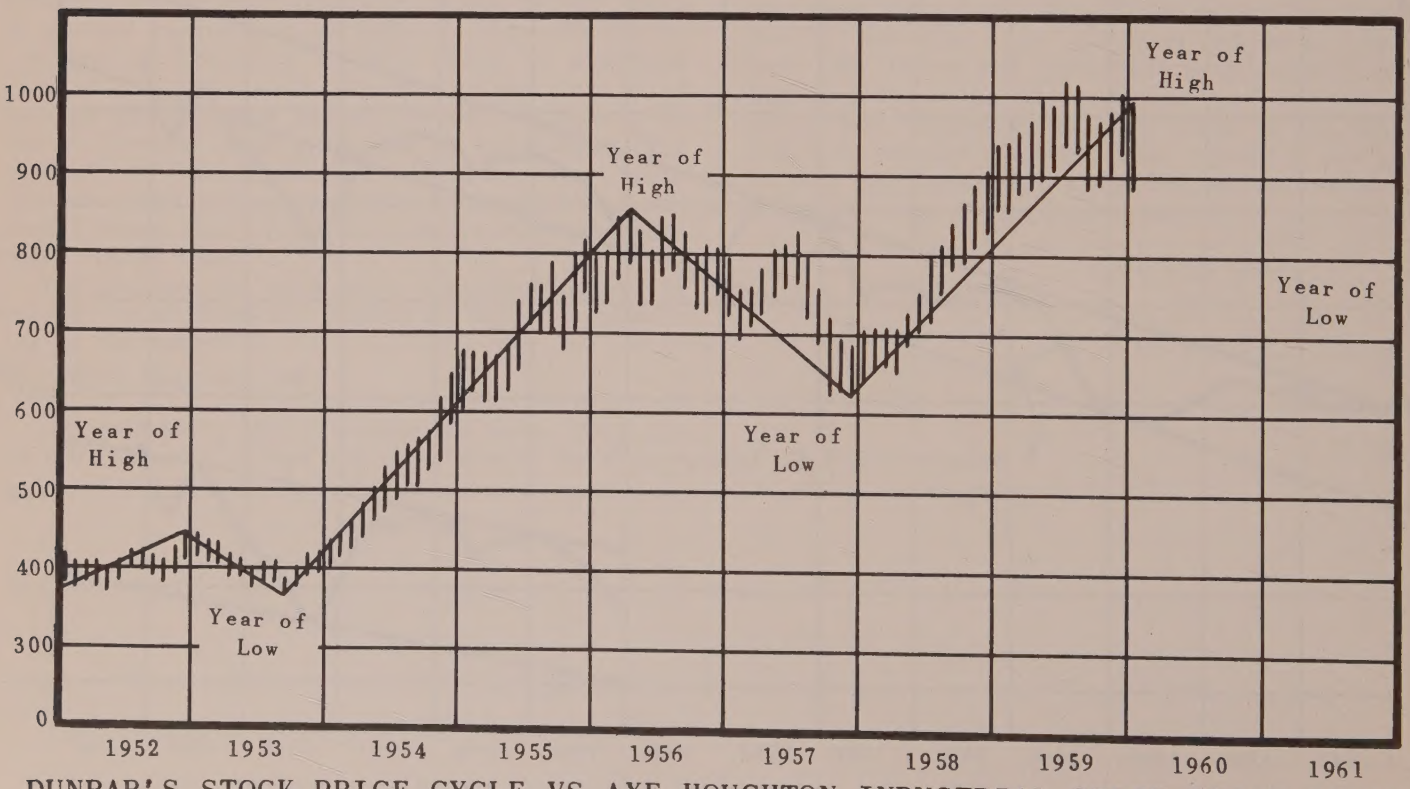
The 1956 high was above the 1953 low.

The 1957 low was below the 1956 high.

A 1960 high has been above the 1957 low.

The batting average of this cycle is still 1.000.

The next scheduled year of low is 1961. As this cycle has worked five times out of five possibilities, *since you have known about it*, it would appear a safe bet that 1961 will see a value below the 1960 high.



DUNBAR'S STOCK PRICE CYCLE VS AXE-HOUGHTON INDUSTRIAL STOCK PRICE INDEX

TABLE 1

The 46-Month Cycle in Common Stock Prices 1834--1959

by Veryl L. Dunbar

A. Years of cycle low according to the pattern 3-4-4-4-4-4-4 and repeat, and the index of common stock prices for the years of low.

B. Years of cycle high according to the pattern 3-4-4-4-4-4-4 and repeat, and the index of common stock prices for the years of high.

C. Percent appreciation, low to high.

D. Percent depreciation, high to low.

Common stock prices are the Axe-Houghton Index of Industrial Stock Prices for the years 1883 to date carried back to 1854 by Clement and Burgess and connected with an index of stock prices from the year 1834 as published in a *Review of Economic Statistics*. The index shown for each year is the high or low index for the month in which the high or low occurred in that particular year.*

A		B		C	D
Cycle Low		Cycle High		% Appreciation	% Depreciation
Year	Index	Year	Index	Low to High	High to Low
1834	17.2	1837	22.0	27.9	37.7
1838	13.7	1841	12.2	(1.1)	38.5
1842	7.5	1845	17.5	133.3	5.7
1846	16.5	1849	19.0	15.2	6.8
1850	17.7	1853	27.0	52.5	40.0
1854	16.2	1856	21.2	30.9	57.1
1857	9.1	1860	19.0	108.8	36.3
1861	12.1	1864	37.5	209.9	37.1
1865	23.6	1868	39.7	68.2	20.4
1869	31.6	1872	46.8	48.1	42.7
1873	26.8	1876	39.6	47.8	36.4
1877	25.2	1879	49.0	94.4	12.2
1880	43.0	1883	59.4	38.1	45.1
1884	32.6	1887	73.6	125.8	19.6
1888	59.2	1891	78.4	32.4	6.4
1892	73.4	1895	70.0	(4.6)	37.1
1896	44.0	1899	94.8	115.5	30.8
1900	65.6	1902	102.4	56.1	35.0
1903	66.6	1906	135.4	103.3	46.5
1907	72.4	1910	131.8	82.0	30.0
1911	92.2	1914	111.6	21.0	14.2
1915	95.8	1918	162.5	69.6	14.0
1919	139.7	1922	160.4	14.8	19.8
1923	128.6	1925	198.6	54.4	25.2
1926	148.5	1929	428.8	188.8	64.1
1930	153.8	1933	154.2	0.3	26.9
1934	112.7	1937	293.4	160.3	57.5
1938	124.8	1941	170.0	36.2	29.4
1942	120.0	1945	280.4	133.7	21.4
1946	220.4	1948	283.0	28.4	24.7
1949	213.0	1952	440.4	106.8	17.1
1953	365.0	1956	856.8	134.7	27.3
1957	623.0	1960	990.9	59.1	
1961	?	1964	?		
		TOTAL		2,392.6	963.0
		AVERAGE		72.5	30.1

*FIGURES 1834 THROUGH 1949 FROM THE BULL MARKET BY VERYL L. DUNBAR AS PUBLISHED IN BARRON'S FOR JUNE 30, 1952, PAGES 11 AND 12. FIGURES AFTER 1953 ADDED BY FOUNDATION.

() DENOTES DECREASE

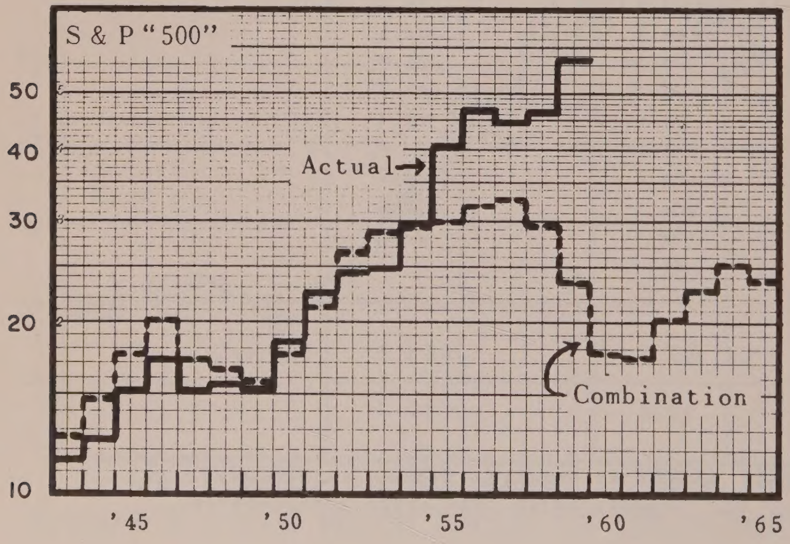
The Cycle Round-up

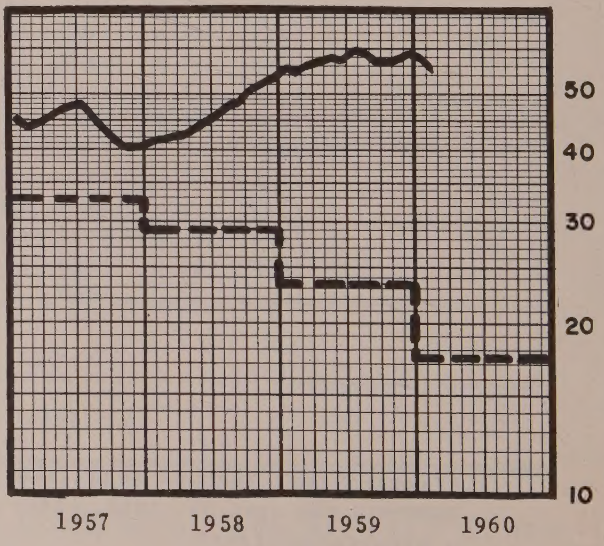
APRIL 1960

Series	Unit	Month	Amount
Aluminum Production	Thousand tons	Dec	163.0
Automobile Factory Sales	Thousand cars	Jan	669p
Bond Yields—Moody's Domestic Corporate	Per cent	Jan	4.91
Cocoa Bean Prices—Accra, New York	Cents per pound	Dec	30.9
Copper Prices— Electrolytic, New York	Cents per pound	Jan	33.65
Cotton Consumption	Thousand bales	Dec	800
Corn Prices— No. 3 Yellow, Chicago	Cents per bushel	Jan	114.4
Egg Prices—Extras, Large, Wholesale, Chicago	Cents per dozen	Jan	25.9
Hog Prices—Wholesale, All Grades, Chicago	Dol. per 100 lb.	Jan	12.08
Liabilities of Failures— Dun & Bradstreet	Million dollars	Jan	53.7
Residential Building Contracts—F. W. Dodge Corp.	Million dollars	Dec	993
Shoe Production	Million pairs	Dec	48.4
Soybean Prices—No. 1 Yellow, Illinois points	Cents per bushel	Jan	211
Stock Prices— Standard & Poor's Combined Index	1941-43=10	Jan	58.00
Sunspots	Number	Jan	Not yet available
Unemployment	Per cent	Jan	6.09
Wheat Prices— No. 1, D. N. S., Minneapolis	Cents per bushel	Jan	224.5

STOCK PRICES

Standard & Poor's Combined Index averaged 58.00 in January and 55.70 in February.





THE RHYTHMIC NATURE OF ANIMALS AND PLANTS*

By

Frank A. Brown, Jr.

Reprinted from
Northwestern University Tri-Quarterly
Fall, 1958

We are fortunate if, once in a year's time, we find an article worthy of reproduction, intact, as a Foundation Reprint.

This is such an article.

We are indeed grateful to the Northwestern University *Tri-Quarterly* and to Dr. Brown for their permission to use this article.

Over the past year we have occasionally reported on Dr. Brown's work.

He has been concerned with the physical relation of living things to their environment, and with the basic nature of the rhythms found in all living things. This article deals with the result of thousands of experiments by Dr. Brown and his associates, experiments designed to trace the natural rhythms of plants and animals, and to relate these rhythms to the constantly changing environment.

We are pleased to announce that Dr. Brown has recently been elected to the Committee for the Foundation for the Study of Cycles.

Foundation for the Study of Cycles
Reprint No. 40
April, 1960

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Frank A. Brown, Jr.

That New Haven oysters should open their shells regularly at the time of high tide in New Haven seems appropriate to Connecticut's reputation as the land of steady habits. But that those same oysters transported to Evanston, Illinois, should change their habits so as to open at the time of high tide in Evanston if Evanston had a tide, suggests a mystery.

Frank A. Brown, Jr., is Morrison Professor of the Biological Sciences at Northwestern, and Consultant in the Department of Invertebrate Zoology, Marine Biological Laboratory, Woods Hole, Massachusetts. He has a wide membership in the various learned societies in his field, in which he holds a number of offices, and has frequently been called upon as adviser in marine affairs of concern to the United States Government.

The article printed below was first delivered as an Alumni Fund Lecture at Northwestern University on April 24, 1958, and subsequently at a number of other universities. The implications of his experiments are fascinating to the layman and of controversial challenge to his professional colleagues.

THE RHYTHMIC NATURE OF ANIMALS AND PLANTS*

Living things inhabit a world replete with rhythms. Nearly every aspect of the physical environment exhibits rhythmic changes. From the submicroscopic atoms, comprising systems of negatively charged electrons sweeping in orbits about positively charged nuclei, to our solar system of planets including the earth revolving in their orbits about the sun, the observable, relative stability of nature is dependent upon such rhythmic or periodic changes.

The external physical environment of living organisms displays well-known rhythmic changes. The rotation of the earth on its axis relative to the sun provides the daily 24-hour period with its extensive changes in light, temperature, and humidity. The rotation of the earth relative to the moon provides our lunar-day periods of 24 hours and 50 minutes. The lunar-day fluctuations in light and temperature are, however, feeble compared with those of the solar day. These two daily rhythms cooperate with the orbiting of the moon about the earth to provide monthly cycles of 29½ days, the period separating two consecutive times of synchronization of solar and lunar noons. Both sun and moon are responsible for producing tides in the oceans and atmosphere of the earth. The sun is the more influential of the two in the case of the atmospheric tides, and the moon the more influential for the oceanic ones. The solar and lunar tides of the atmosphere are associated with more subtle physical changes such as barometric pressure, cosmic radiation, gravity, magnetic field, and atmospheric electrical potential. The earth also revolves about the sun with its axis oriented in such a manner as to yield the annual rhythm of the seasons. Finally, the sun itself rotates on its own axis with an average 27-day period, and since the sun's surface is not uniform, an additional rhythmic change with a 27-day frequency is imposed upon the surface of the earth.

The physical environment of living things is truly a composite of rhythms.

It might be presumed, therefore, that living things, as complex, delicately balanced, physico-

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Research program on rhythmicity was aided by a contract between the Office of Naval Research, Department of the Navy, and Northwestern University.

chemical entities lying at a level between atom and solar system, persist as stable beings only through some kinds of comparable rhythmic fluctuations about mean values. In fact we do not need to go beyond our own bodies to be impressed with the existence of such rhythms. Man has daily cycles of many processes such as wakefulness, blood sugar concentration, blood-cell count and body temperature. For example, our body temperature tends to be lowest, other factors equal, about 5 to 6 in the morning and highest about 5 to 6 in the evening. Another familiar cycle is the reproductive, which follows the lunar month.

Very widespread among the animal and plant kingdoms are daily, lunar-tidal, lunar monthly, and annual cycles of innumerable activities; and where biologists have sought them, 27-day cycles have been observed as well. It can be said without equivocation that rhythmicity is the rule in living things. These rhythms are often highly useful ones. Like the boxer in the ring, the organism in its rhythmic environment is able to yield before the periodic blows and to advance after them. In its rhythmic physical environment, the rhythmic organism is therefore adapted, figuratively speaking, to make hay while the sun shines, in preparation for the dark, cold nights.

The spectacular, complex character of the rhythmic nature of living things first impressed me about 25 years ago as a young visiting investigator at the Bermuda Biological Station. One of the fascinating pastimes was to sit on the laboratory jetty in the evening after dark with the water beneath illuminated by an electric lamp. Myriads of living things, attracted by the light, would swim into the area. All the creatures were easily identified because biologists had thoroughly studied the flora and fauna of the Island and published extensively upon them. But one night about 10 o'clock, the water suddenly became charged with ghostly transparent, strange shrimp. We captured some but a careful search revealed that these had never before been seen at Bermuda. They were sent to the British Museum, where it was learned that only one male specimen had ever before been caught—and that one in the Indian Ocean about 50 years earlier. It turned out, these shrimp are abundant at Bermuda, but swarm in hordes only for an hour or two just before midnight near the time of new moon. A 2-year study by Wheeler of the fluctuation in abundance of these shrimp at different times of the lunar month showed one swarming peak to occur two days after new moon, and a second larger one 3 to 4 days before new moon. No one knows yet where they conceal themselves the rest of the time.

Such a precise lunar rhythm of swarming to assure the bringing together of large numbers of males and females for breeding and maintenance of the species is commonplace. Another and better-known example of lunar swarming for breeding purposes is that of the Palolo worm of the southwest Pacific. At a predictable time of day at the times of the October and November 3rd quarter of the moon, elongated posterior ends of these worms, filled with reproductive cells, break off and swarm from the burrows in the coral rock in such numbers that they are readily scooped out of the sea. The predictable occurrence of these delectable, edible worms determines the time of feast days for certain south-sea islanders.

Coming closer to home, newspapers of coastal areas of California indicate for their readers the exact hour when they can go to their sandy beaches and expect to catch a highly prized, small edible fish, the Grunion, as they swarm in from the open sea and throw themselves onto the beaches. This they do from April through June at that exact time of the month when the sun and moon are cooperating to produce the highest high tide of the month, and a few minutes after the exact moment of high tide. These fish normally reproduce by depositing eggs and sperm in pits they dig in the wet sand just out of reach of most high tides. Here the young fish develop and are ready to take off to sea at the time of the next monthly high, high tide.

We don't have to select illustrations from animals alone, since even seaweeds are known which have lunar-monthly reproductive cycles. These are critical for the species; they synchronize the production of eggs, and the sperm which must fertilize them.

Examples of solar-day and annual rhythms of living things in nature are legion. Every one of us can think of organisms that are habitually nocturnal, diurnal, or crespuscular in their daily time of activity, and axiomatic are our spring and fall waxing and waning of the activities of innumerable plants and animals. And along the shores of our oceans where the tides monotonously rise and fall with lunar-tidal frequency, 50 minutes later each day, are corresponding rhythms of activity of the organisms that live there: some, like oysters, which filter their food from the sea-water are active only when covered by water at flood tide; others, like the foraging fiddler crabs, scour the beaches for food exposed at ebb tide.

Animals, futhermore, do not have to dwell on the sea-shore to display a lunar-tidal rhythm. There is the often-quoted observation of the reef-heron, which lives on the mainland of Australia up to 30 miles away from its feeding ground on the reef where it preys upon animals exposed at low tide. Each day this bird departs from its roost on its trip to the reefs just at the proper time to take advantage of the low tide,—50 minutes later each day. This phenomenal timing ability led one writer to remark, "Here is a sixth sense if ever there was one."

Another kind of example of a daily rhythm is seen in birds such as the starlings, which, in their north-south migrations in Europe, have been demonstrated to utilize the sun as a compass through holding their bodies at a fixed angle relative to it. But the sun during a daylong flight gradually moves across the sky from east to west. Kramer and Matthews both reported that the birds continuously corrected for the changing position of the sun in order to maintain a fixed, straight, compass course. Kramer spectacularly demonstrated this by placing birds in a domed enclosure possessing an artificial sun fixed in one position. Under these conditions, the direction of orientation of the birds relative to the artificial sun gradually changed during the day, exactly as one would have predicted on the basis of the rotation of the earth. Some beach-fleas which migrate up and down the beaches have similarly been proven by Pardi and Papi to use both sun *and moon* as their compass, correcting with equal facility and accuracy to the normal movements of each.

A final kind of illustration to familiarize one with roles of rhythms in organisms comes from studies of the time-sense of organisms. Beling found that if honey-bees are fed sugar-water at a particular place and *time of day* for a few days, they will continue to come back to the same place at the same time of day. They even continue to come back for several days when food is no longer provided. This kind of time-training can be accomplished only on a 24-hour periodic basis. One can *not* teach them, say, to feed at regular 19-hour intervals. This learning process, therefore, in some manner involves their 24-hour rhythm.

The foregoing selected examples of biological rhythms suffice to illustrate their widespread distribution and a few of the innumerable ways they may be put to use by living things. Now let us pass on to some studies of the mechanisms of the rhythmicities.

The most obvious explanation of the daily rhythms that occurs to one is that the organisms are simply responding to the daily cycles in light, temperature, or humidity, and that the lunar-tidal rhythms of shore-dwellers are simply direct responses to the rhythmic ebbing and flooding of the tides. This hypothesis was easily testable, and was, *in fact*, first tested about 200 years ago. Many plants were known to show a sleep-rhythm involving the drooping of the leaves by night and their elevation by day. Zinn, in 1759, found that plants would still show the sleep rhythm when no light or temperature changes occurred. This observation was confirmed and studied extensively early in this century using the bean seedling, and such work is now continuing actively in the laboratory of Professor Bünning and his associates at the University of Tübingen, in Germany. A general method of recording automatically the leaf movements on a slowly rotating drum is illustrated in Figure 1.

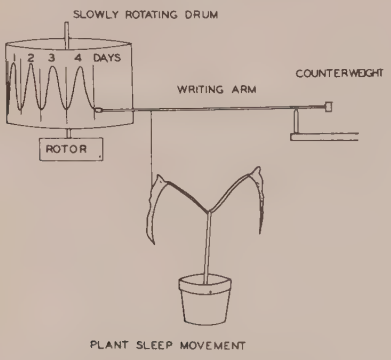


FIGURE 1. Apparatus for automatically recording sleep-movements in the bean seedling.

The persistence of the daily rhythmic processes in living things in conditions constant with respect to all factors generally conceded to influence the organisms has now been demonstrated by numerous investigators for living things representing the gamut of the animal and plant kingdoms, and ranging from single-celled microorganisms to the most complex of multicellular larger ones.

Fiddler crabs in nature start to blacken their skin about sunrise in the morning to hide themselves better from their predators, and to screen their delicate internal organs from the intense sunlight of the unshaded beaches, and about sunset they rapidly blanch until their bodies are pale silvery gray. This is more evident for their legs than for their bodies, since the shell covering the legs is quite transparent. Even crabs captured and maintained in constant conditions in a photographic darkroom continue for weeks or months to darken and lighten each day in synchrony with their relatives still free in their natural day-night environment.

Another, and very interesting property of these rhythms persisting in darkness is that they may be easily reset so that events in the rhythm occur at times of day other than the normal ones. This may be illustrated by the crab color-change rhythm. If this is proceeding normally in constant darkness and temperature (the top line of Figure 2), showing maximum darkening at noon and blanching at midnight, and we simply, for two or three days, leave lights on in the darkroom from midnight to noon, we find at the end of this treatment that the crabs still possess an accurate daily rhythm of color-change which persists in darkness indefinitely, but now (as in the second line in Figure 2) it has been shifted so that the color changes occur at an earlier time of day, by 6 hours. They now darken most at 6 a.m. and blanch most about 6 p.m. In a comparable manner we may set the actual time of the color changes in the 24-hour rhythm to any time of day, and there it will remain until reset. The third line of Figure 2 shows crabs which were subjected to 3 lighted nights and darkened days; the cycles are inverted. An alternative way to reset the cycles is through giving the crabs, while in constant darkness, experimental cycles

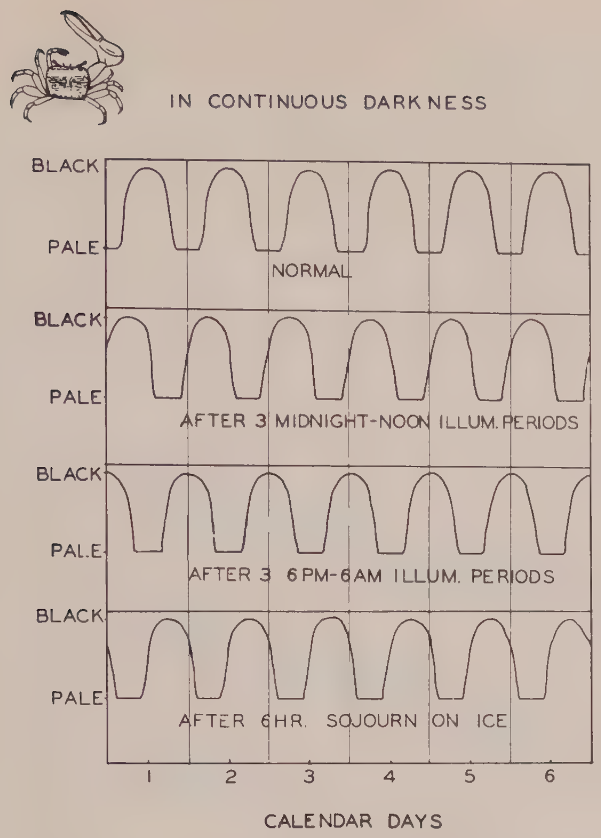


FIGURE 2. Daily rhythm of color-change in fiddler crabs, and some of its experimentally altered phase relationships.

of abrupt temperature changes. High temperatures act like light, lower temperatures like darkness. A third way to reset them is simply to place crabs with normal cycles in constant darkness on ice-cubes for the number of hours one wishes to set back the cycles. When taken off the ice the crabs' color-change rhythm picks up right where it left off when they were first iced (fourth line of Figure 2) and hence the phases are slow by a time correlated with the period of chilling. It is as if self-starting 24-hour clocks were stopped near freezing temperatures.

Fiddler crabs in nature romp most actively on the beaches seeking food about the time of low tide. When these crabs are brought into the laboratory and kept in vessels in a photographic darkroom, then like those still left on the beaches, they continue to show their greatest running activity at the times when it is ebb tide on their native beaches, and remain relatively quiet at the time of flood tide. The time of maximum running occurs therefore later each day at the expected lunar-tidal rate. If in the same darkroom at the same time we place two groups of crabs, taken from two different beaches on which the time of low tide was different by several hours, each group of crabs may continue to signal the time of low tide on its own beach. So, simultaneously in the same crabs deprived of all ordinary cues relative to time of day or tide, there persists, on the one hand, a solar-day rhythm of color change and, on the other, a lunar-tidal cycle of spontaneous activity.

Studies comparable to these, using numerous other kinds of animals and plants, have demonstrated quite clearly that, like the daily, the lunar-tidal rhythms do not depend upon any known kind of external cues for the measurement of the lunar-period lengths.

The 24-hour rhythm seems very deeply ingrained in organisms. We showed a number of years ago that even if rhythms seemed completely halted, as in the instance of color change in crabs held in very bright light for 10 or 12 days, a regular rhythm would reappear at once when the crabs were replaced in darkness.

It has been satisfactorily demonstrated that an organism need never have experienced a single normal daily cycle in its life, and yet be capable of exhibiting a precise daily cycle. Hence the cycle can not be contemplated in any sense as a period of day-length remembered by the organism. It was shown long ago that beans grown in constant darkness show no rhythmic sleep movements, but a single brief light shock will start off a persisting 24-hour rhythm, the time of day of awakening-onset, a function of time of the light shock. Fruit flies normally, as they are about to complete their development, emerge from their pupal cases, as fully active flies, about daybreak. Dr. Brett, in my laboratory, showed, however, that if a batch of eggs are laid and development is caused to occur wholly in darkness, flies emerge at all hours of the day. But if during the development of the fly larvae in darkness, a single flash of light, as brief as one minute, is given them, then the flies will emerge from their pupal cases, up to days later, after completing their development and pupating, at the same time of day as the time the light flash was given. The light flash could not have imparted information as to the length of a 24-hour period to render this possible. The flies behaved quite as if they all had operating 24-hour rhythms of emergence but had had nothing by which to set them to the usual time of day. The brief light flash seemed to be treated by all the developing flies as the onset of a dawn, and with this, all the rhythms were synchronized. Flies normally emerge at dawn.

A deep-seated daily rhythmicity of still unknown significance was discovered recently by Professor Bünning and his associates. This is a rhythm of swelling of the nucleus of cells of a number of plants. In the daily changes the nucleus is largest about six in the morning and smallest at noon. I have spoken of this rhythm as deep-seated because the cell with its contained nucleus constitutes the fundamental unit of organization of all living things, whether plant or animal.

It is a commonly experienced phenomenon when we have made long east to west, or west to east airplane trips that we have moved to a new longitude without having reset our own internal 24-hour rhythms. If, for example, we had lived for a time in New England and were accustomed to awakening at 7 in the morning, and now flew to take up residence in California, we would find ourselves, in California, awakening and disconcertingly being quite wide awake, about 4 a.m. Pacific Standard Time. In doing this we would still be following our 24-hour rhythm; this is, of course, 7 a.m. Eastern Standard Time. But after a few days of experiencing the California social and day-night rhythms, we would have reset our rhythm to Pacific Standard Time and would have the same experience, but in reverse, were we to fly back to New England.

The foregoing is an example of a fundamental property of rhythms of living things which has given biologists more information. My associates and I performed an objective experiment of this nature with fiddler crabs a few years ago. Crabs, which were changing color in a darkroom in our laboratory on Cape Cod, Massachusetts, at the usual times, dawn and dusk, were divided into two equal-sized batches and sealed in light-proof cartons. One batch was carried by airplane to be opened in an experimental darkroom at the University of California the next day. Synchronously, by prearrangement, the other group was opened in a darkroom on Cape Cod. The rhythms of color change in the two lots of crabs on the two sides of the continent were studied. The times of darkening and lightening for the two batches were carefully compared. Both were on Eastern Standard Time. The crabs that had travelled to California kept their rhythm on Eastern Standard Time, both during the trip, and during the six days in California that they could be studied. The average time difference for the 6-day period was only 12 minutes; this was within the error of our measurements. The crabs showed no tendency to shift their rhythms to accord with the dawn and dusk of California.

From this last experiment it was possible to draw certain conclusions. 1) Since during the day of their westward trip, the crabs had been subjected to an artificial day of 27 hours and 20 minutes with respect to any and every "local-time" factor that possessed its 24-hour period as a consequence of the rotation of the earth relative to the sun, the crabs clearly could measure one 24-hour period without any kind of clue, even a subtle one, of this nature. 2) Once in California where rhythms of many physical environmental factors were once again 24-hour ones, the crabs could retain an accurate 24-hour rhythm in a new time-relationship relative to the external ones. 3) To reset their rhythms to Pacific time, the crabs needed exposure to one or more natural California light cycles.

The year following this study on the crabs, a completely comparable experiment was performed by Renner, using the time sense of honey-bees. Completely duplicate bee-training rooms were built and furnished in Paris and in New York. Bees were trained to come to a particular spot in the Paris room for food at a particular time of day. Once trained the bees were sealed in a container and flown to the room in New York. The bees, now in New York, came to the feeding spot at the proper time for Paris. They were retrained in New York and flown back to Paris. In Paris they came to feed at the proper time for New York. This confirmed completely our crab experiments.

These experiments, however, did not prove that a rhythm of some subtle external factor was not essential to the organismic 24-hour rhythm since there are certain important 24-hour rhythms in the environment that are on universal time. By universal time is meant that the rhythm affects all regions of the earth's surface in the same ways at the same instants. Such a factor is the daily fluctuation in the 300,000-volt potential difference which exists between the surface of the earth and one of the outer shells of our atmosphere, the ionosphere. By one of these universal-time cycles the 24-hour period could conceivably be imparted to the animals even while they are travelling. On the other hand, the living rhythmic system might be completely independent of all external cycles.

We have seen thus far that the daily rhythms of living things in constant darkness, like the clocks in our homes, can measure accurately 24-hour periods whether they are set at the normally correct time of day, or have been reset to register an incorrect time. As the mathematician or physicist would describe this, the rhythms in the living things need not have locked phase-relations with any external physical rhythms. On the contrary, there is a freely labile relationship. This adjustability of the biological cycles is a very useful characteristic. Absence of this property would make the rhythms comparable to alarm clocks in which the time of day or the ringing of the alarm could not be altered.

This brings us to another of the interesting properties of the rhythms of living things, namely, that many are known regularly to gain or lose a few minutes every day. Some are even known which regularly gain or lose two or three hours a day. Such a one as the last is the spontaneous activity of the field mouse, or the white rat. Both of these animals, when kept in constant darkness, may exhibit an accurate 24-hour cycle of running with about 12-hour periods of activity alternating with about 12-hour periods of rest, but when kept in an unchanging low illumination have their daily cycles of running longer than 24 hours. In the rat we found them to be quite regular and 25¼ hours in length. In Figure 3 starting at the top the blackened areas indicate the times of day of running during 70 days in constant dim light. To begin with, the rat, like any well-adjusted rat, ran only during the early morning and the evening hours. Since the rat started to run 75 minutes later every day the daily period of running was occurring in the daytime in less than 2 weeks. The period of running can be seen to scan the day more than three times during the 70-day period from November 13 through January 20. When, at the end of this time, the rat was placed in darkness (the last 25 days in Figure 3), the rhythm became an accurate 24-hour one, the rat running at the same time each day. In other words, the rat appeared able to indicate accurately the time of day by its running only when it was in continuous darkness.

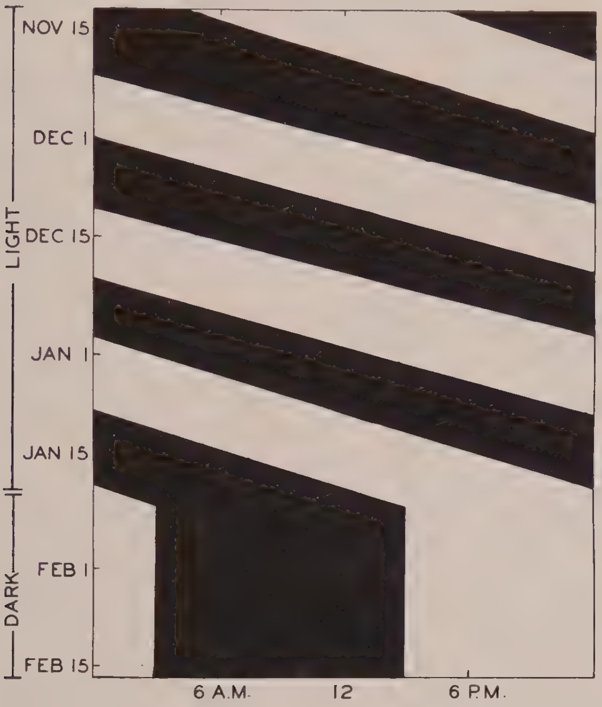


FIGURE 3. Shaded area indicates time of day of running activity of one male white rat during 70 days in dim, constant illumination followed by a 25-day period in continuous darkness.

In the bean seedling not only may the sleep rhythm often have natural periods a little different from 24 hours in constant darkness at ordinary room temperature, but the length of the periods seems to be inherited; some genetic strains have longer-period natural rhythms in these constant conditions than others. One strain whose rhythmicity has been studied very extensively possesses a 28-hour cycle.

The clocks of man are simply instruments with built-in cyclic changes corresponding to the length of the natural daily cycle, and by their appropriate divisions into hours, minutes, and seconds, enable us to know at any given instant, at just what point in the daily cycle we have arrived. The daily cycles of living things are often referred to as depending upon "biological clocks," since the daily rhythms of all living things imply the possession by the organism of a means of measuring accurately the period of the day.

By the same token, living things seem also to possess a basic timing mechanism indicating the lengths of lunar periods, or a "lunar-clock." And since a number of living things are known also in constant conditions to measure periods of annual length, they appear also to have "annual clocks." These last two kinds of "clocks" we treat in our annual calendars with their monthly divisions. Therefore, living things behave as if they possessed both "clocks" and "calendars" by means of which many vital processes are appropriately timed even in the absence of such well-known daily, monthly, and annual changes as those of illumination and temperature.

The characteristics of the rhythmicity in living things of the kind that have just been described led many investigators of the phenomenon many years ago to the conclusion that living things possess within themselves clock mechanisms that would permit them, when isolated from all environmental changes which were conceded to be able to influence them, to measure off accurately periods closely corresponding to the lengths of the solar-day, and other natural periods. In other words, there was postulated to be operating in living things a completely *independent* complex of rhythms which parallelled in their natural periods the complex known for the external physical environment. This view was entertained despite the fact that certain skeptics of this view had demonstrated over the years that there were circumstances in which the rhythms of living things could not be shown in constant conditions. Stoppel could not observe them in a basement in Iceland during the time of the midnight sun; Cremer cound not find them in a deep salt-mine in Germany, nor Hempel and Hempel in Lapland during the time of the midnight sun. The investigators who discovered these very interesting exceptions claimed or implied that the rhythm in the bean seedling or insects which they used, depended upon rhythmic changes in the environment which still, in some manner, pervade all ordinary so-called laboratory constant conditions. Under these special circumstances, the rhythmic external factor was postulated to be not present.

But biologists, like other scientists, are human and often not always quite as fully objective as is commonly believed. It was for them easier to rationalize objections to the way an experiment was conducted, or to claim correctly that no one had yet confirmed the experiment, than to abandon an hypothesis which, except for these little disrupting facts, provided a consistent view.

At any event, all the evidence at hand seems to suggest the possession by living things of a rhythmic phenomenon superficially resembling a recording system with about one complete circuit per day. This system appears capable of having any form of behavior pattern impressed upon it, whereafter it keeps repeating this pattern, until either it fades away, or some new pattern is made to replace it.

Such a resemblance to a recording system was lucidly shown by Professor Bünning for the bean seedling. If we have a bean seedling displaying in constant low light a daily sleep rhythm, drooping its leaves at night, and now give it a brief brighter light stimulus during the nighttime phase, we see that not only does the light cause a momentary brief elevation of the leaf but now the plant continues to do it day after day at the same time even in constant darkness. From the standpoint of rhythmicity, the basic question is, what keeps the recording system going at an essentially uniform speed, sometimes quite precisely one circuit per day? One widely held view, as has been mentioned earlier, is that the living thing possesses within itself some machinery for measuring off quite independently from the environment periods of time, but since all known living machinery is predominantly chemical in nature, this would clearly have to depend upon the rates of chemical reactions.

There is a very general rule, the van't Hoff rule, applying equally to chemical reactions and to living processes, which states that as the temperature rises, the rate of chemical processes speeds up, and as we lower temperature, the rate slows down. The rate of biological processes usually more than doubles for every 18 degrees F. rise in temperature. This law is the basis of the universal use of refrigerators to reduce the rate of food spoilage, or bacterial decay. Now if the rhythmic timing mechanism were biochemical and wholly inside the organism, one would expect a speeding up of the rhythm with increasing temperature, and a slowing down with decreasing temperature. For example, if at 70 degrees F. the period of the rhythm was 24 hours at 90 degrees F. we would expect it to be about 8 or 10 hours and at 50 degrees F. about 50 hours. When we studied critically this problem with fiddler crabs about 10 years ago, we found to our amazement that through a wide range of temperature the period of the rhythm remained the same, precisely 24 hours. The animals had available some method of time-measuring that was independent of temperature, a phenomenon quite inexplicable in any currently known mechanisms of physiology, or, in view of the long period-lengths, even of chemical reaction kinetics. Following this discovery it was rapidly shown in our laboratory and in those of others that the daily cycles of other animals and plants were similarly temperature-independent. The most spectacular recent demonstration of temperature-independence involved a study of dried plant seeds. These have been shown to have an *annual rhythm* in their capacity to germinate even when stored in constant conditions. Bünning and his associates in Germany recently found that dried seeds showed an accurate annual rhythm whether they were stored at 3 degrees *below* zero F. or at 120 degrees F. At the former temperature, 35 degrees below the freezing point of water, all vital processes would normally have been expected to be at least temporarily halted.

There are also many powerful drugs and poisons which are known to slow down living processes greatly. One of these is cyanide. None of these ordinary depressing drugs, though the doses may be so great as barely to permit the organism to survive following their removal, will in any manner slow down the rhythms. These extraordinary relative immunities of the rhythms of plants and animals to temperature and drugs certainly begin to strain one's confidence that they are wholly inside the living things. And what sort of autonomous series of reactions could possibly be imagined in which the organism, with all its transformations occurring during that year, could possibly provide information as to just when one year had elapsed, even when not harrassed by drugs or freezing temperatures? Even a comparably resistant 24-hour cyclic mechanism is virtually impossible to conceive in any conventional terms of chemistry or biology.

And philosophically, it is very difficult to imagine the living organism as possessing an internal clock, wholly independent of all external factors, of the remarkable absolute precision it must have to account for the rhythmicities. On the other hand, if the organism had even while in the so-called "constant conditions," daily, lunar, and annual rhythms being impressed upon it by external physical factors, these might constitute the fundamental clock-system which could pace, or provide reference rhythms, for the labile biological rhythms possessing approximately the same frequencies. Some biologists, forgetting that they first made the quite arbitrary assumption that the biological rhythmic processes and the clocks which time them are one and the same thing, claim as already proven that the clocks need no external information through the demonstration that the rhythms are freely modifiable and often have periods other than the natural ones. It might be recalled, however, that using our ordinary pocket or wrist watches, set to the correct time of day and running at their usual speed, we can readily change the pattern of a precise daily behavior pattern, or time accurately a 22- or a 26-hour rhythmically recurring event, both of which capacities we would probably lose forthwith were our watches suddenly to be taken from us.

The temperature-independence of the frequencies of the organismic rhythms was a very difficult fact for physiologists to credit, especially since the general concensus was that the timing of the cycles was exclusively inside the organisms. This was an apparent evasion of a time-honored rule of physiology. But this spectacular fact became demonstrated unequivocally so easily and in so many laboratories that it was necessary that the problem be faced. The reaction of most investigators was to begin to postulate various kinds of hypothetical mechanisms by which organisms might have internal clocks that would perhaps do this. A few such speculations have been advanced in the literature of the past two years.

In our laboratory, where the complete *temperature-independence* was first demonstrated and its implications stressed, our reaction was different from that of the others. It seemed to us that the phenomenon was so extraordinary that perhaps still another of the sacred tenets of physiology was invalid. This other one was the fundamental premise of the experimental physiologist that when he keeps his organisms in constant illumination, temperature, humidity, and all other factors *he has conceded to influence them,* the organism is truly in constant conditions. So time-revered was this view that even to question it seemed a sacrilege. And we knew when we did it, that the opposition of tradition would be tremendous to overcome.

In a sense the view that we took was simply a more sophisticated one of the type taken by the numerous skeptics of a decade or more ago, when told of the persistence of rhythms in constant conditions. They doubted that the investigator had really controlled all daily fluctuating factors as well as he thought he had.

An experiment we performed with oysters had raised similar doubts in our minds, too. The U.S. Fish and Wildlife Service had shipped us a batch of healthy oysters they had collected in New Haven Harbor. Since the tides are, you recall, of lunar-day frequency, we studied in the oysters the time of lunar-day of maximum opening of their shells for feeding in pans of sea-water in a photographic darkroom in Evanston. For about the first two weeks they opened their shells most at the time of high tide in New Haven Harbor; then they appeared to forget their home tidal times and for the next two fortnights they opened their shells almost at the times of lunar zenith and nadir in Evanston, a 3-hour time change. These new times were the times of maximum gravitational attraction by the moon as it produces the well-known lunar tides of our atmosphere.

In order to examine further the question as to whether the external factors were actually controlled, we sought a biological process which was common to every living thing. For this we selected metabolism. Metabolism underlies all animal and plant activities and thus we were no longer limited to the study of special forms. The rate of metabolism could be measured by the rate at which the living thing used oxygen. Also, the higher the rate of metabolism, other factors equal, the greater the amount of spontaneous activity displayed by an animal, and hence we could also measure metabolic rate by studying spontaneous activity. It did not require a very long initial study to demonstrate beyond all reasonable doubt that living things, *even while in so-called constant conditions,* had access to outside information as to the time of day (or position of the sun), time of lunar day (or position of moon), time of lunar month, and even time of year.

I shall not try my readers with either the detailed methods of study or the mathematics of the analysis, but shall simply summarize for you some of the principal facts. The most complete of our studies have been done on young potato plants, small pieces of potatoes with sprouting eyes prepared as illustrated in Figure 4. Occasionally while being studied in our recording apparatus they even developed new potatoes. Potatoes were selected for this study for two reasons. 1) The potato tuber is essentially a generous reservoir of stored food, and hence, there was no problem of feeding the organisms while they were sealed for long periods in constant, dark conditions, and 2) these seemed about as inauspicious a living thing as one could expect to find as far as rhythms were concerned. Briefer, parallel studies with other plants and animals have suggested that what we have found for the potato holds in a general manner for all other living things as well.

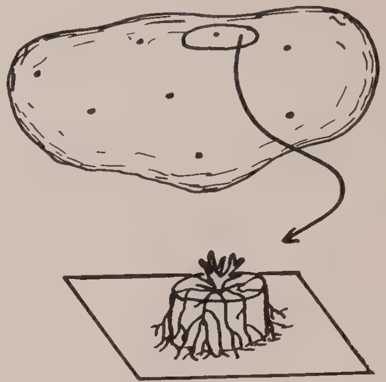


FIGURE 4. Method of obtaining the potato plants used in the study of metabolic cycles.

It is well known that there are solar and lunar tides of the atmosphere. These are reflected in rhythms of barometric-pressure change. In the daily cycle (the upper curve in Figure 5A), the pressure, *on the average,* always rises during the early morning hours to a high about 10 o'clock and then falls to the low point of the day, during the middle to late afternoon, the time of the low point depending on the time of year. This is a precise average 24-hour rhythm. The potato has similarly a precise average 24-hour cycle of metabolism (the solid line of the lower curves in Figure 5A) with a minimum rate at midnight and a maximum rate at 6 in the afternoon. This average daily cycle can be shown to include the average of two kinds of daily oscillations: the dashed-AA'A''- and the dotted -BB'B''- ones in Figure 5A. Both the barometric pressure cycles and the potato cycles exhibit irregularities from

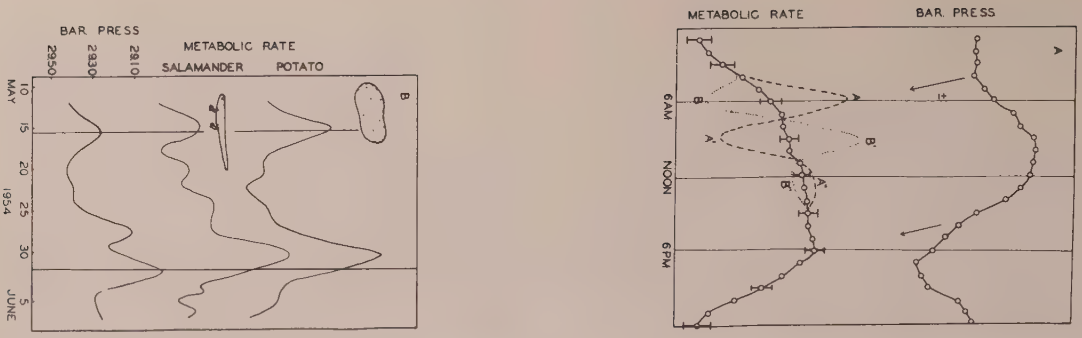


FIGURE 5A. The general form of the daily barometric pressure cycle during a summer month (upper curve). The mean daily cycle of potato O_2-consumption (lower curve).
FIGURE 5B. A comparison of the day to day changes in metabolism of both potatoes and salamanders with the concurrent barometric pressure changes.

day to day. The barometric pressure cycles are distorted by large changes due to still unknown forces, which are associated with weather changes. The important fact for us here is that the potato is informed of how fast the pressure is rising in the morning and falling in the afternoon. This we know first because how high, or how low, the potato metabolism is at 6 in the morning (points A or B Figure 5A) of any given day is simply related to how fast the barometric pressure was changing from 2 to 6 the preceding morning. And, secondly, how high the rate of metabolism in the potato is at 6 in the evening of any given day is related to how fast the barometric pressure was changing from 2 to 6 the preceding afternoon.

Hence the potato in the form of its daily metabolic fluctuation, even in constant conditions of *pressure,* through being hermetically sealed in rigid containers, is in effect informing us through indicating in its metabolic changes what the weather distortions were in the regular pressure cycle of yesterday. And whatever the means by which this information reaches the potato, the same information is providing the potato, figuratively speaking, with information as to what the weather-associated, barometric pressure will be the day after tomorrow, by the height of the afternoon peak of metabolic rate. This is tending to trace out the form of the barometric pressure changes but doing so two days in advance. This is illustrated by the month-long study of potatoes and salamanders shown in Figure 5B. Notice how both kinds of living things generally vary inversely with the barometric pressure change (bottom curve), but both tend to anticipate the pressure changes by an average of two days. In fact, every living thing studied in our laboratory during the past 3 years,—from carrots to seaweeds, and from crabs and oysters to rats,—has shown this capacity to predict very safely beyond chance the barometric pressure changes usually two days in advance. It is interesting to contemplate the problem of a meteorologist sealed, incommunicado, for weeks or months in constant conditions, and asked to give 2-day weather predictions—or for that matter even to tell you the weather today.

The potatoes also indicate to us that they are, while sealed in constant conditions, obtaining information about another well-known environmental daily rhythm, namely that of *high-energy background radiation.* This is so penetrating that it pervades all ordinary buildings and containers. This radiation is highest about 6 in the morning and lowest between noon and 6 p.m. The daily range, or cycle amplitude, in the radiation, though averaging about 2%, varies greatly and unpredictably from day to day. The potato cycles also show variable total range, or amplitudes, from day to day. But, the amplitude of the potato cycles on a given day is very clearly related to the amplitude of the background radiation cycle the day before. The greater the fluctuation in radiation yesterday, the greater the fluctuation in metabolism today.

The potato sealed in constant conditions also obtains information as to the outdoor air temperature. As clearly seen in Figure 6, the higher the outdoor temperature up to about 57° F., the higher the amplitude of the daily metabolic fluctuations. This relationship is reversed for higher temperatures. As everyone knows, there are clear daily and annual rhythms in air temperature.

The potato in constant conditions also exhibited

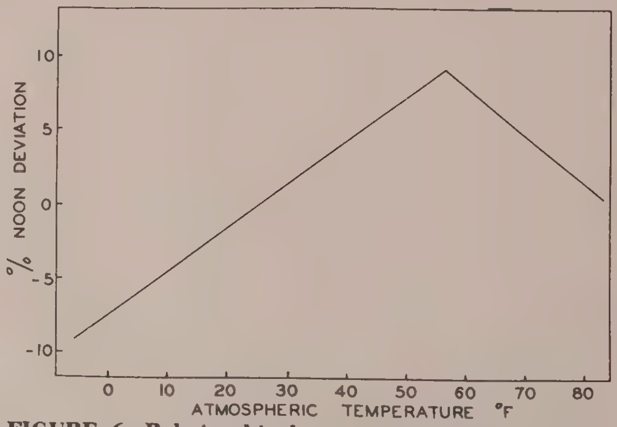


FIGURE 6. Relationship between percentage change in metabolic rate of potatoes between midnight and noon, and the outside air temperature.

a *lunar-monthly rhythm* of metabolism during a full-year period of study. As seen in Figure 7A the rate was lowest at the time of new moon and highest at the time of third quarter. The rate of metabolism was 20% higher at 3rd quarter than at new moon. There was also a monthly cycle in the form of the daily cycles. As seen by the dotted curve in Figure 7B, the daily cycles were depressed during the morning hours, at the time of new moon, and as shown by the solid line, quite symmetrical and high, with a maximum at noon, at the time of the third quarter. The sun is, obviously, always at its highest point in the sky at noon. The time of day the moon is highest depends on the time of month. Over full moon, it is midnight; over new moon it is noon. These changes in the form of the daily cycles through the month seem logical if we think of the sun and moon having qualitatively the same effect on metabolism, the maximum accelerating action of each on metabolism occurring about 6 hours later than the time it reaches its zenith in the sky.

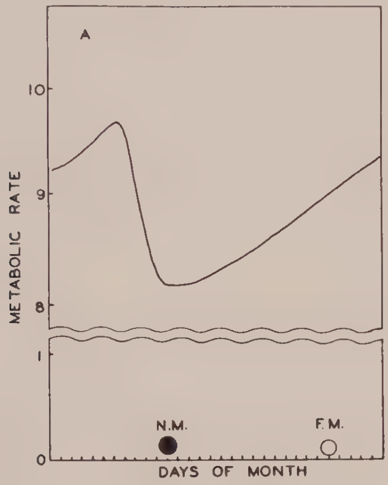


FIGURE 7A. **The variation in average metabolic rate in the potato with time of the lunar month.**

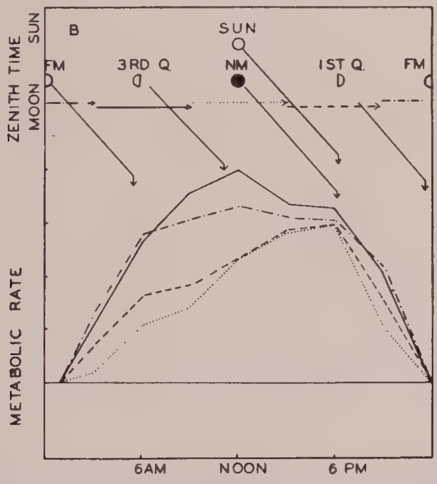


FIGURE 7B. **The change in form of the average daily metabolic fluctuation with day of month.**

An annual cycle in the form of the daily cycles was also found to exist in constant conditions. The average monthly values for two years of study are shown in Figure 8A. The cycles were lowest in amplitude in January and February, and highest in September, October, and November during both years. There was also an annual cycle in general metabolic rate in the constant conditions (Figure 8B). The highest rate occurred in May, and was about twice that seen in the lowest month, October.

Collectively these facts provide incontrovertible evidence that even when we have thought we have excluded all forces influencing the living things, there is, nonetheless, cyclic information, unquestionably with all the natural periodicities of the atmosphere imbedded in it, still impressing itself upon the organism. Living things might conceivably possess inherited, regular rhythms, but it is quite inconceivable that they are born with an inherited plan of all the erratic temperature, barometric pressure, and background-radiation fluctuations which are to occur during their lifetime. So far we don't know what the specific nature of the factor or factors may be which are directly effective on the living organism. This is one of the most important and exciting problems before us in our continuing research.

But to suggest further that the forces involved in our problem may be in part determined by other forces arriving on our earth even from outside of our own solar system, we have obtained some striking similarities of our biological metabolic rhythms, with fluctuations in cosmic radiation raining on our outer atmosphere predominantly from distant outer space. This discovery was the outcome of a comparison of metabolic daily cycles in potatoes, seaweeds, and fiddler crabs during the springs and summers of the two years, 1954 and 1955. Between these two years, the daily metabolic cycles of all three species seemed to have, in good measure, turned upside down. In the fiddler crabs, for example (as shown in the upper solid curve in Figure 9), the highest rate of metabolism for the day in July, 1954 was about 2 p.m.; in July, 1955, as seen in the lower solid curve of Figure 9, this was near the time of day of the lowest rate in the daily metabolic cycles. In searching for a possible difference that might have occurred in some subtle external physical factor between the two years, some data upon the fluctuations in cosmic radiation occurring at the specific times of these studies were loaned to me by Professor Simpson of the Enrico Fermi Institute of the University of Chicago. It was clearly evident that just as the crab daily cycles seemed to have been inverted between these two specific periods of study, so had the cosmic-ray cycles for the same two periods (the two broken-line curves). And furthermore, the general forms of the crab and radiation cycles were striking mirror images of one another. Similarly with the potatoes and seaweed, the forms of the metabolic cycles we had measured seemed clearly related in

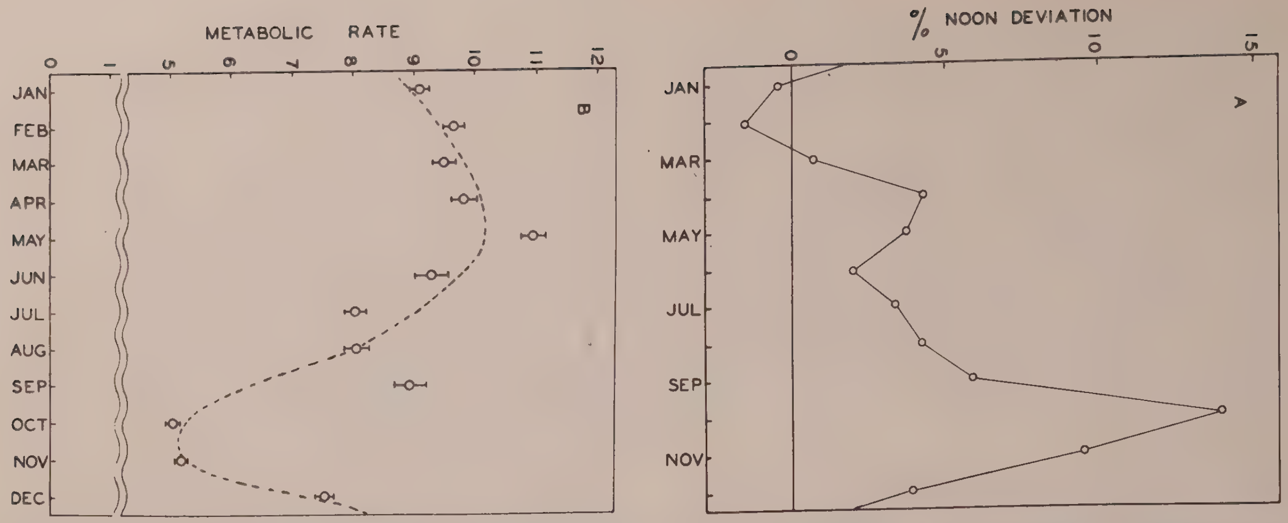


FIGURE 8A (left). The relationship between the percentage change in metabolism of potatoes between midnight and noon and the time of year. **FIGURE 8B (right).** The variation in average metabolic rate with time of year.

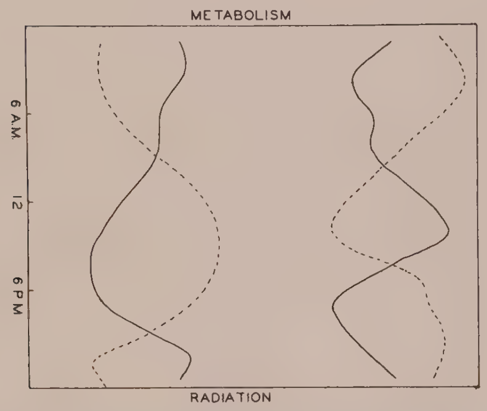


FIGURE 9. Comparison of the average daily cycles of cosmic radiation (broken lines) and fiddler crab metabolism (solid lines) for a single summer month in each year, 1954 (upper pair of curves) and 1955 (lower pair of curves).

some manner to the cosmic-ray cycles.

It is obvious that the specific forms of these cosmic-ray cycles could not have become evident to the living things in terms of fluctuations in any physical factors which are commonly conceded to influence them, such as light, humidity, and temperature. This would hold true even were the organisms exposed to the natural fluctuations of an open meadow. Clearly then, there must be still unidentified physical factors affecting life. And it now seems reasonable to postulate that these latter factors are very important to the living things in the timing of their rhythmic processes, or, in other words, in the operation of their clocks and calendars.

The thesis supported in this article, namely that during the timing of cycle-lengths of the rhythms in animals and plants in so-called "constant conditions" the organisms are still continuously receiving from the external environment information about the natural geophysical cycles, removes some of the romantic glamour inherent in the alternative view, that all living things must possess within them uncannily accurate clocks capable of measuring, independently, periods ranging in length from the day to the year. On the other hand, its implications are tremendous with respect to the potentialities involved through the demonstration that living things are sensitively responding to additional kinds of stimuli at energy levels so low that we have hitherto considered the living organism completely oblivious of them. These latter potentialities may soon loom importantly in many areas of biology and medicine, especially in such problems as animal navigation and behavior.

The demonstration that the physical environment of living things is organized *temporally* in terms of still unknown subtle and highly pervasive forces which the living organisms can resolve encourages one to speculate that there may be some comparable subtle and pervasive *spatial* organization of the environment which is contributing at least in a small way towards accounting for geographical distributions or periodic migrations of organisms.

Letters

CORN AND HOG CYCLES

Dear Mr. Dewey:

Your discussion of corn and hog cycles is right down my alley. . . I made my first corn-hog graph about 1920, and it has affected my bank account ever since. Have grown much corn in my time, also hogs.

To raise corn without hogs is unthinkable, also hogs without corn. . . it is a matter of supply and demand with the peaks of one opposite the valleys of the other.

Another factor is the weather. A rainy spring delays corn planting and brings lower yield; drought also limits yield. Improved technology, hybrid seed, irrigation, government interference, and general economic fluctuations further complicate the situation.

Indianapolis, Indiana N. D. McKinstray

Comment: We have not yet attempted to correlate our work on hog price cycles with the work on corn price cycles, nor have we worked with the corn-hog ratio. These are obvious future projects.

This does illustrate what we keep repeating, *ad nauseam*: you need to have a knowledge of all the factors (including the cycles) before you can make an intelligent forecast. G. S.

THE STOCK MARKET

Dear Mr. Dewey:

In the September 7th issue of *Barron's*, Mr. Joseph E. Granville of E. F. Hutton & Co. wrote an article about Barron's Confidence Index and its use as a forecasting device in the stock market. This index is the ratio between the average yield of Barron's 10 highest grade corporate bonds and that of the Dow-Jones 40 bonds, and is a measure of confidence in the *bond* market. The ratio is high when investors buy lower-grade bonds and low when they seek refuge in higher grade bonds.

Mr. Granville projects peaks in this index ahead two to four months to predict peaks in the stock market, and likewise valleys in the index to call the bottoms of declines in the market. He seems to prefer the two month or sixty day projection.

When plotted, this index seems to follow the 17-week cycle in stock market prices only invertedly so.

This index made peaks on September 15, 1958, January 26, 1959, June 1, 1959, and September 21, 1959, with valleys approximately midway between the peaks. These peaks were 19, 18, and 16 weeks apart respectively.

Furthermore, the highest peak in the index in 1957 appeared in May and was 68 weeks before the peak in September of 1958 - 68 weeks being about the period necessary for four 17-week cycles.

I wonder why this cycle is present in the bond market? When this cycle is favorable in the more active stocks, is it unfavorable in the bond market.

Perhaps this approach might give us a little more knowledge about this particular cycle (and perhaps others as well) and get us a little closer to the cause of this cycle.

Kingston, Massachusetts G. Webster Dyer

* * *

Dear Mr. Dewey:

Arthur Weisenberger and Company prepare a chart showing the percent of return obtainable on the Dow-Jones Industrials from 1900 to the present. Also shown is the cost in dollars of each dollar of dividend.

Every investor should know that, at least since 1900, whenever the *price* of one dollar of dividend income goes up to $30.00 or more, trouble and declining stock prices have followed. Not immediately but surely.

Such a chart serves as a guide to "how high is too high" in the stock market.

The stock buyer of last August paid over $34.00 for $1.00 of dividend income. Time will prove whether he was any smarter than the man who paid over $33.00 for $1.00 of dividend income back in 1929.

Fontana, California Richard J. Ferguson

POLITICS

G. B. Wilson of Hemit, California sent a clipping from the October 21 issue of *Financial World* which lists the following tabulation of liberal and conservative periods by Arthur Schlesinger Jr.;

Liberal Periods	Conservative Periods
1765-1787	1787-1801
1801-1816	1816-1829
1829-1841	1841-1861
1861-1869	1869-1901
1901-1919	1919-1931
1931-1947	1947-1961

According to the tabulation, "If past rhythms hold, the conservative period should about run its course by 1961-62." Editorial comment by *Financial World* pointed out that each of the liberal periods contained inflation, and all but one had a serious war, so that although the continuance of the cycle might make some people happy, the idea is spine tingling to others.

The Geisinger Indicator

The Federal Reserve Board's seasonally adjusted Index of Industrial Production went up from 165 in December 1959 to 169 in January 1960

The Geisinger Indicator continued to decline in October (June 1960 when advanced). It reached -3.2.

The First Difference Indicator went up to 3.83 in December. The sharp upturn in production following the end of the steel strike is responsible for the recent advance in this Indicator.

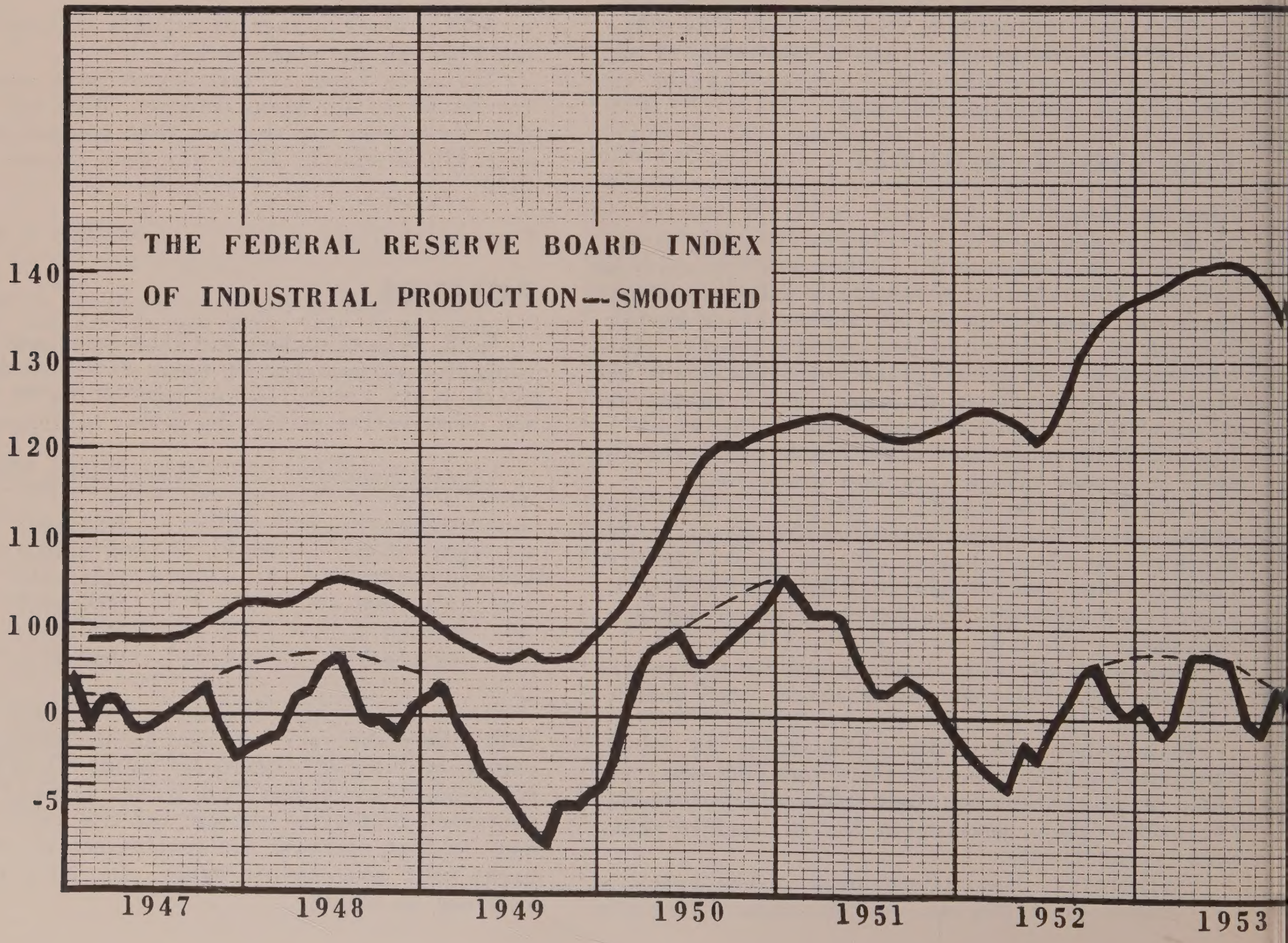
The Modified Geisinger Indicator turned in October (June 1960 when advanced). It went from -5.20 in September to -5.03 in October

The appearance last month of a Geisinger Indicator which cut -2.00 going down introduced a definite note of warning, even though part of the decline may have been merely a reflection of the steel strike. The Geisinger Indicator has continued going down, and there is as yet no reason to change our interpretation that caution is now advisable. Remember that this warning applies only to industrial production, and to things that behave in the same way.

February 24, 1960 E. R. Dewey

Month	F.R.B. Index After Revision	Geisinger Indicator	First Difference Indicator	Modified Geisinger Indicator	Timing Advanced 8 Months
Sep-1959	157	-2.2	-3.00	-5.20	1960-May
Oct	154	-3.2	-1.83	-5.03	Jun
Nov	155r	*	1.00	*	Jul
Dec	165	*	3.83	*	Aug
Jan-1960	169p	*	*	*	Sep

p - preliminary; r - revised; * - not yet available



Explanation

The Modified Geisinger Indicator is an index which, in the past, has usually gone up and down ahead of the Federal Reserve Board Index of Industrial Production. The Modified Geisinger Indicator thus throws some light on the future.

The Modified Geisinger Indicator is the sum of the Geisinger Indicator and The First Difference Indicator.

The Geisinger Indicator was invented by Robert Geisinger. It is derived from figures which are published monthly in the **Survey of Current Business.** (Col. 3 of the table.)

The First Difference Indicator, is merely the amount by which the smoothed F. R. B. Index is above or below the value for the preceding month. It registers the rate of advance or decline. It has some forecasting value, too. (Col. 4 of the table.)

The sum of these two Indicators is the *Modified* Geisinger Indicator. It is advanced by eight months and plotted as the bottom line of the chart. (Col. 5 of the table.)

The F. R. B. Index of Industrial Production measures physical production in the U. S. A. It has nothing to do with stock prices. (Col. 1 of the table.)

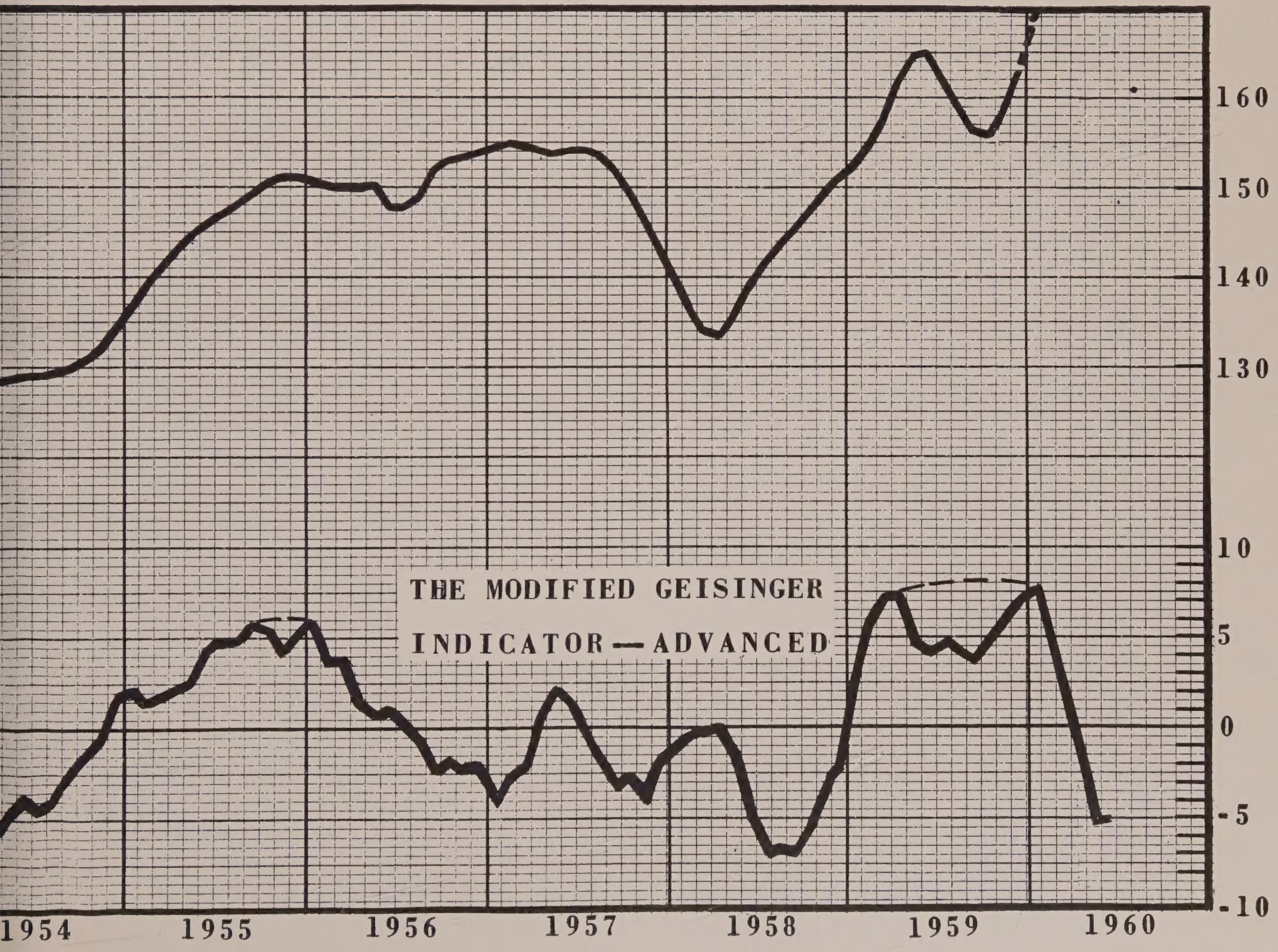
The smoothed values of the F. R. B. Index are plotted as the top line on the chart. It is smoothed by a 3-month moving average posted to the second position. The latest actual monthly Index of Production is recorded by a dot.

Interpretation

In the past, when the *Geisinger* Indicator going up, has cut +2, good business has followed; when, going down, it has cut -2, bad business has followed.

The important *turns* of the *Geisinger* Indicator and the *Modified* Geisinger Indicator often come 8 or 9 months before corresponding turns in Industrial Production. This fact gives some idea of what is around the corner. To help you to grope your way into tomorrow the Modified Geisinger Indicator is advanced 8 months. Where it is now, Industrial Production may soon be.

The degree to which the two curves correspond can be seen by inspection of the chart. The correspondence is general rather than specific. It is the broad sweep of the lines which is to be watched. The dashed lines which are added show how the eye should follow the Indicator.



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